

BOVEDA, the Bolivian Vegetation Ecology Database: first stage, the Chacoan forests

Jaime Oliveira¹, José Antonio Molina¹, Gonzalo Navarro²

¹ Biodiversity, Ecology and Evolution Department, Complutense University, Madrid, Spain

² Community Ecology, Bolivian Catholic University “San Pablo”, Cochabamba, Bolivia

Corresponding author: José Antonio Molina (jmabril@ucm.es)

Academic editor: Jürgen Dengler ♦ Received 29 March 2022 ♦ Accepted 24 September 2022 ♦ Published 24 October 2022

Abstract

Bolivia is a country exceptionally rich in biodiversity and home to about 20,000 vascular plant species and 15 plant formations. Therefore, it is particularly important to document the biodiversity of this territory. The aim of the Bolivian Vegetation Ecology Database (BOVEDA; GIVD ID SA-BO-005) is to record floristic and ecological data of Bolivian vegetation. In the first stage, the database hosts 320 relevés from one of the most unique biogeographical units in the country, the Chaco. In total, 633 species belonging to 114 families have been recorded. Data on vegetation structure, soil, flooding regime and geomorphology have also been stored. The following nine vegetation structural types were identified: (1) deciduous forests of alluvial plains on well to moderately well drained soils; (2) deciduous to semideciduous Chaco forests transitional to the Andes; (3) deciduous and sclerophyllous Cerrado thorn-woodlands and shrublands transitional to the Chaco (Abayoy); (4) xeromorphic thorn shrubland and thickets on vertic, poorly drained soils; (5) woodlands and savannas on sand dunes and aeolian surfaces; (6) freshwater swamp forests; (7) saltwater swamp forests; (8) phreatophytic forests; (9) deciduous to semideciduous Chaco forests transitional to the Chiquitania. Further steps will be to incorporate new types of vegetation already recorded in the field such as Altiplano shrublands, Andean wetlands, Andean *Polylepis* forests, and vegetation of the dry inter-Andean valleys.

Taxonomic reference: Jørgensen et al. (2015).

Abbreviations: BOVEDA = Bolivian Vegetation Ecology Database; GIVD = Global Index of Vegetation-Plot Databases.

Keywords

Bolivia, Chaco, database, dry forest, Neotropics, phytosociology, soil-vegetation relationship, vegetation classification

GIVD Fact Sheet: Bolivian Vegetation Ecology Database (BOVEDA)

GIVD Database ID: SA-BO-005		Last update: 2022-09-16
Bolivian Vegetation Ecology Database (BOVEDA)		Web address:
Database manager(s): Gonzalo Navarro (gonzalonavarrosanchez@gmail.com); José Antonio Molina (jmabril@ucm.es)		
Owner: Gonzalo Navarro, José Antonio Molina		
Scope: Bolivian Vegetation Ecology Database (BOVEDA) includes floristic and ecological data of the vegetation types in Bolivia. All vegetation plots record the co-occurrence of vascular plants. Most plots also comprise substrate information (soil/water features). Currently, the database includes mostly original georeferenced relevés of forests in areas typically of 2000 m ² , conducted mainly on the Bolivian Chaco, covering ca. 128 000 km ²		
Abstract: Bolivian Vegetation Ecology Database (BOVEDA) is a floristic and ecological database of the Bolivian vegetation		
Availability: according to a specific agreement	Online upload: no	Online search: no
Database format(s): Excel	Export format(s): CSV file	
Plot type(s): normal plots	Plot-size range (m²): 100 to 4000	
Non-overlapping plots: 320	Estimate of existing plots: 1000	Completeness: 32%
Total no. of plot observations: 320	Number of sources (biblioreferences, data collectors): 6	Status: completed and continuing
Countries (%): BO: 92; PY: 5; BR: 3		Valid taxa: 633
Formations: Forest: 98% = Terrestrial: 98% // Non Forest: 2% = Aquatic: 2% (Fresh water: 2%)		
Guilds: all vascular plants: 10%; only trees and shrubs: 80%		
Environmental data (%): altitude: 29.3; slope inclination: 8; other soil attributes: 4.69; other attributes: vegetation series (27%); type of formation (37%); canopy height (17.2%); slope orientation (1.56%); degradation status (9%); soil specifications (54.4%); electrical conductivity (µS): 4(.69%); additional info.: (in Spanish, transcribed literally from the field journal): 89.4		
Performance measure(s): presence/absence only: 3%; cover: 97%		
Geographic localisation: GPS coordinates (precision 25 m or less): 100%		
Sampling periods: 1990-1999: 60%; 2000-2009: 40%		
<i>Information as of 2022-09-16; further details and future updates available from http://www.givd.info/ID/SA-BO-005</i>		

Introduction

Bolivia has one of the highest ecosystem diversities in the Neotropics (Jørgensen et al. 2015). The country includes four biogeographical regions: Amazonian, Brazilian-Paranáean, Chacoan and Tropical Andean (Navarro and Maldonado 2002; Navarro and Ferreira 2009; Rivas-Martínez et al. 2011). This biogeographical mosaic leads to an immense amount of biodiversity in 1,098,581 km². This includes 12,245 known vascular plant species with an additional 8,000 more expected to be described in the future, leading to a total richness of approximately 20,000 species (Jørgensen et al. 2015; Moraes and Sarmiento 2018).

The appearance of databases of relevés, and their compilation in global archives of metadata, meant a paradigm shift in the study of vegetation and biogeography. The GIVD (Dengler et al. 2011) and the sPlot Consortium (Bruelheide et al. 2019) lead this paradigm shift. The Bolivian Vegetation Ecology Database (BOVEDA) was created to fill a gap in the lack of information on the outstandingly biodiverse country, and to facilitate the sharing of data and connect researchers (Figure 1). For this purpose, our project aims to include floristic and ecological data for the vegetation types of the country, and for the metadata to be available online in the GIVD archive. Here we present the first step of the database, focusing on the Chaco.



Figure 1. Logo of the Bolivian Vegetation Ecology Database (BOVEDA). The logo characterizes an Altiplano plant-landscape of cactus and shrubland in the background and in the foreground the silhouette of the South American continent including within it that of Bolivia bordered by the name of the database (Bolivian Vegetation Ecology Database) and its acronym (BOVEDA).

Study area

As a first step in BOVEDA development, we included our data from the Chacoan region (Neotropical-Austroamerican Realm, Rivas-Martínez et al. 2011) in Bolivia. The Gran Chaco is one of the great biogeographic units of the Neotropics, and one of the most interesting and distinct eco-regions in South America (Cabrera 1971; Navarro 2011; Rivas-Martínez et al. 2011), including territories from five different countries. The Gran Chaco is divided into the northern Chaco (Boreal Chaco) and the southern Chaco (Austral Chaco) along a decreasing temperature gradient. Furthermore, the dry and wet parts of the Chaco can be distinguished along an increasing rainfall gradient from west to east (Cabrera 1971, 1994; Navarro et al. 2011). One of the vastest extensions of the Chaco Boreal is found inside Bolivia's borders, a lowland xeric biome (Navarro and Molina 2021), covering more than 127,700 km², of which 34,411 km² are part of the largest protected area in the country, the Kaa-Iya of the Gran Chaco National Park and Integrated Area (Taber et al. 1997).

The bioclimate of the Bolivian Chaco is xeric, with a dry and semiarid precipitation zone (Navarro and Maldonado 2002; Navarro 2011). From a geological point of view, the Bolivian Chaco was formed at the end of the Pliocene to the beginning of the Pleistocene, from the alluvial fans of the rivers Parapetí, Gande, Pilcomayo and Teuco-Bermejo (Navarro and Maldonado 2002). This sedimentary origin leads to a lithology rich in sands, silts and clay deposits, and the different combination of these three grain sizes in the soil texture as well as the small topographical differences determine the internal drainage degree of the soils and their flooding regime, which is one of the major factors determining the type of forest formation (Navarro et al. 2011).

Data collection

A total of 320 georeferenced relevés were gathered from fieldwork conducted by the third author mainly in the Bolivian Chaco and some relevés from neighbouring countries (Figure 2). Sampling was made between the



Figure 2. Map of South American countries and the location of the Chacoan vegetation relevés (brown dots) from Bolivia stored in BOVEDA.

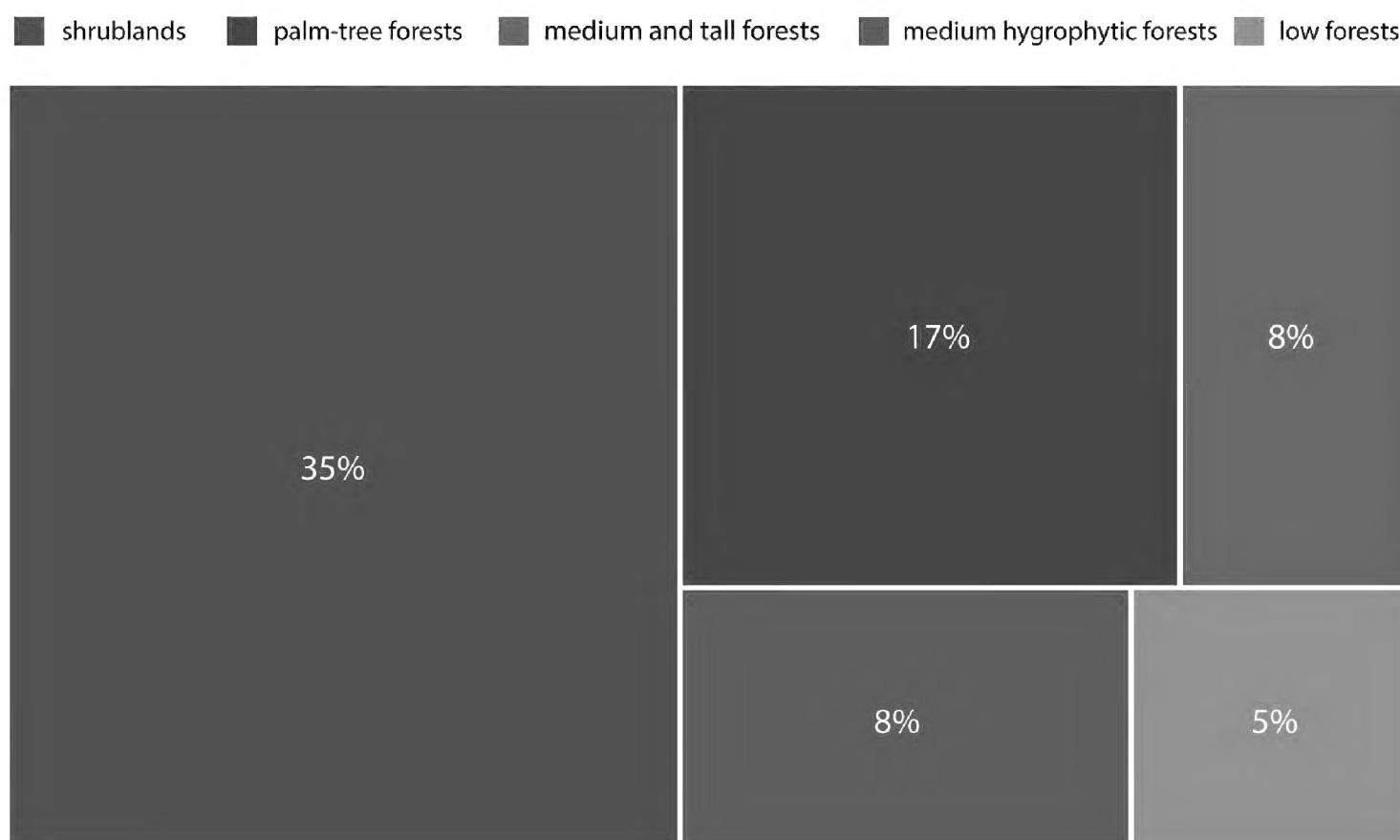


Figure 3. Percentage of the woody vegetation in Bolivian Chaco represented in BOVEDA.

last decade of the 20th century (60%) and the first decade of the 21st century (40%). A balance of sampling in physiognomic types of vegetation was made to reflect the plant-landscape diversity occurring in the area of survey. Almost all the relevés are 2,000 m² on average, with a band-transect design. Plot size is 200 m long and 10 m wide –5 meters on each side of the path-. This method was followed due to the difficulty of accessibility and the impenetrability of the vegetation in many cases. Plant cover estimation was done with the Braun-Blanquet scale (Braun-Blanquet 1979). Most of the sampling focused on terrestrial vegetation (98%, within which the 23% have additional information on epiphytes), although freshwater vegetation were also recorded. In terrestrial vegetation, only woody species were recorded since the sampling period was conditioned by the accessibility to the area in the dry season when herbaceous plants are not developed. Further, tropical forests have a relatively species-poor herb layer compared to temperate forest ecosystems (Sabatini et al. 2022).

Our database is intended to compile vegetation ecology data and this information was considered in the design of the fields of the database. Environmental data includes topographical information, such as altitude (30%) and slope inclination (8%). More than half of all samples comprise substrate information, such as soil specifications (54%), or water electrical conductivity measured in hygromorphic habitats (5%). Soil texture is classified in the field according to USDA (2017).

Vegetation structure and typology is also included in BOVEDA. Thus, information about formation (37%), vegetation series (27%) and canopy height (17%) is provided. Degradation status related to human impact is available for a smaller proportion of plots (9%). Degradation is mostly caused by overgrazing as well as close proximity to human settlements or roads and sometimes fires.

A few relevés (< 2%) do not provide plant cover but only plant presence, which is noted as “p”. Our database comprises a single spreadsheet. The storage format is in xls and the export format is in csv. Upon request, the data are available according to a specific agreement.

Database content

A total of 633 taxa were identified to species level, while 836 were assigned to genus level only and 1010 remained unidentified at the time of survey. The taxa belong to 114 families. Taxonomic nomenclature followed <http://www.worldfloraonline.org> data and the Catalogue of the Vascular Plants of Bolivia, accessible through the Tropicos database by the Missouri Botanical Garden, in <http://legacy.tropicos.org/Project/BC> (Jørgensen et al. 2015; WFO 2021).

The most predominant structure of the wooded vegetation were shrublands and woodlands (35%), followed by palm tree forests (17%) (Figure 3). A preliminary classification of our data suggests that the Bolivian Chacoan woody vegetation encompasses nine different units (Figure 4): (1) deciduous forests of alluvial plains on well to moderately well drained soils (Figure 4a); (2) deciduous to semideciduous Chaco forests transitional to the Andes (Figure 4b); (3) deciduous and sclerophyllous Cerrado thorn-woodlands and shrublands transitional to the Chaco (Abayoy); (4) xeromorphic thorn shrubland and thickets on vertic, poorly drained soils (Figure 4c); (5) woodlands and savannas on sand dunes and aeolian surfaces (Figure 4d); (6) saltwater swamp forests (Figure 4e); (7) freshwater swamp forests (Figure 4f); (8) phreatophytic forests; (9) deciduous to semideciduous Chaco forests transitional to the Chiquitania. An analysis of species revealed that the richest forests were the Chaco forests transitional to the Chiquitania, and the

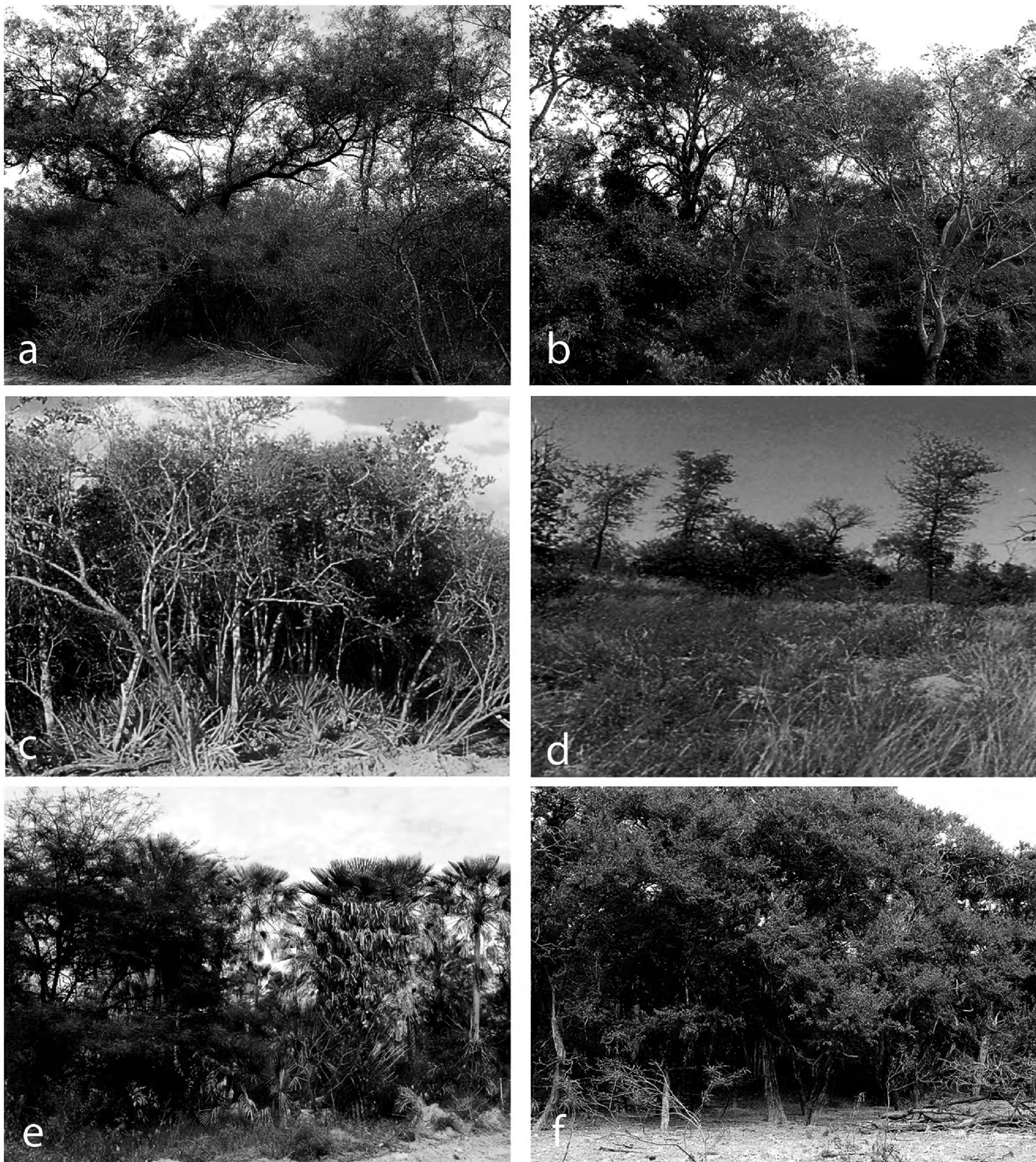


Figure 4. Representative examples of woody vegetation from Bolivian Chaco. a) deciduous forest of alluvial plains on well to moderately well drained soils; b) deciduous to semideciduous Chaco forest transitional to the Chiquitanía and to the Andes; c) xeromorphic woodland and shrubland on vertic, poorly drained soils; d) savanna and woodland on sand dunes and aeolian surfaces; e) saltwater swamp palm forest; f) freshwater swamp forest.

woodlands and savannas on dunes and sands (Figure 5). In contrast, the least rich in species were the swamp forests, while the other forest types were intermediate. According to the floristic information within relevés, the five most species-rich families were *Cactaceae* (23%), *Fabaceae* (22%), *Capparaceae* (12%), *Bromeliaceae* (11%) and *Apocynaceae* (8%).

Future perspectives

BOVEDA, the Bolivian Vegetation Ecology Database (SA-BO-005), is a new project unique in the country, and one of the very few on the South American continent (see Dengler et al. 2011). In this first stage of our project, the relevé count in BOVEDA is already higher than

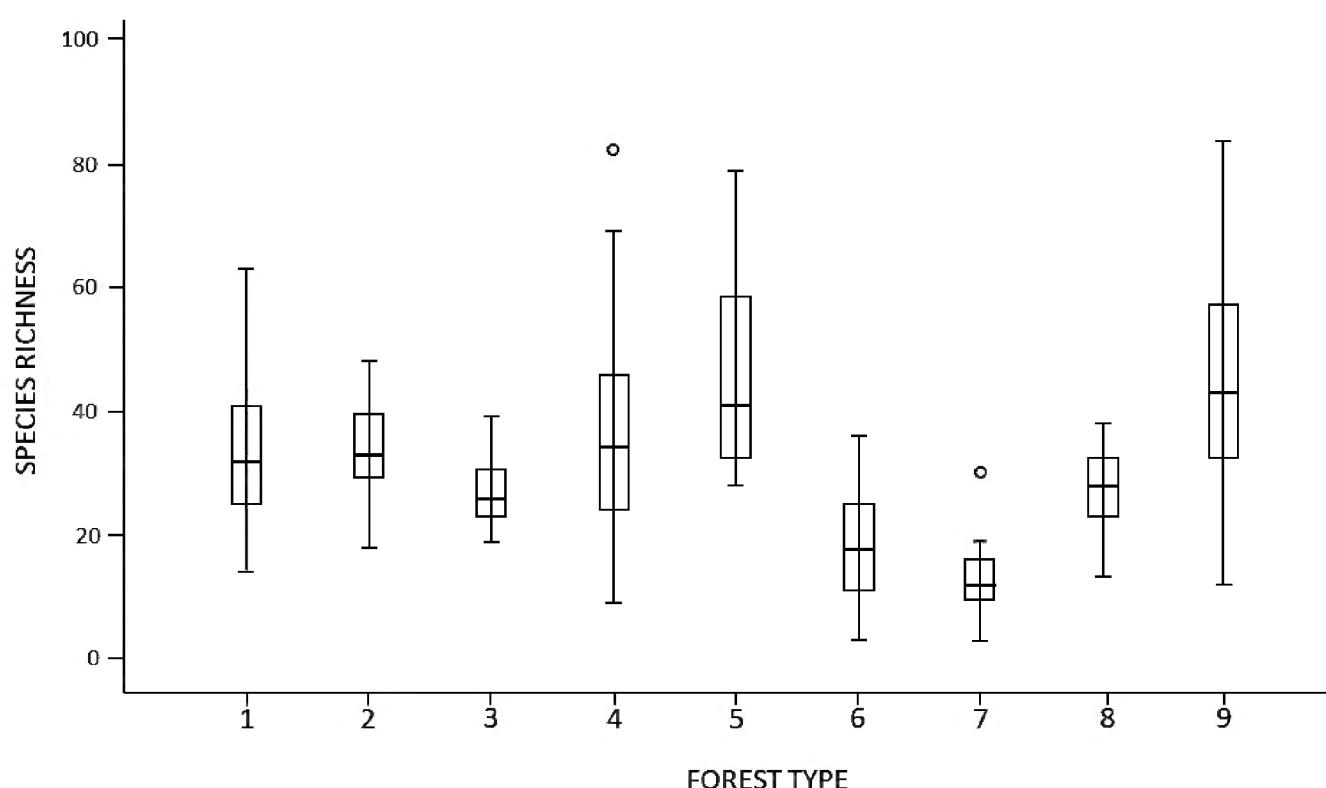


Figure 5. Boxplots representing the woody species richness in nine woody vegetation types in Bolivian Chaco: (1) deciduous forests of alluvial plains on well to moderately well drained soils ($n = 37$); (2) deciduous to semideciduous Chaco forests transitional to the Andes ($n = 8$); (3) deciduous and sclerophyllous Cerrado thorn-woodlands and shrublands transitional to the Chaco (Abayoy) ($n = 7$); (4) xeromorphic thorn shrubland and thickets on vertic, poorly drained soils ($n = 34$); (5) woodlands and savannas on sand dunes and aeolian surfaces ($n = 20$); (6) freshwater swamp forests ($n = 25$); (7) saltwater swamp forests ($n = 7$); (8) phreatophytic forests ($n = 11$); (9) deciduous to semideciduous Chaco forests transitional to the Chiquitania ($n = 51$). Boxes represent the interquartile range of the data (50%), thick horizontal lines show median species richness, whiskers correspond to the variability outside of the interquartile range, and unfilled dots are outliers. Plot size = 2000 m².

in any other GIVD-registered plot database from Bolivia (https://www.givd.info/info_organisation.xhtml).

The BOVEDA is projected to gather data from all eco-regions in Bolivia. After Chacoan vegetation, the following vegetation types will be added as updates: the Bofedales wetlands, the *Polyplepis* forests, the Altiplano shrublands, the dry inter-Andean valleys vegetation, and a set of relevés of Altiplano aquatic flora. With these data collections, the estimate of 1,000 existing plots will be reached, although the intent behind the project is for it to be continued further with data from multiple sources. Further data from past and current fieldwork conducted in areas of other South American countries including Argentina, Chile, Brazil, Venezuela and Ecuador are intended to be stored as well. The expectations of this database rest on two steps: the first extending over the next year will deal with including the raw data of works already published by us (Navarro et al. 2005; Molina et al. 2007; Navarro et al. 2010; Navarro 2011; Molina et al. 2016; Navarro and Molina 2019), while the second will then also include unpublished information from areas such as the inter-Andean dry valleys vegetation or hygrophytic vegetation such as High-Andean wetlands.

With the registration of BOVEDA in the GIVD database and the following actualization updates to come, BOVEDA provides a great opportunity for botanists and

ecologists to use large amounts of original data from areas where published field data are rare and difficult to obtain. Thus, our database offers countless possibilities, such as: biodiversity analysis and mapping, species range mapping, biogeographical analysis, degradation and deforestation measured throughout the years, resistance and resilience measures of ecosystems in cases of perturbation like forest clearing, overgrazing or fire, and many others.

Authors contribution

J.O. conducted database design, entered the data into database. J.A.M. conducted conception and curation of the database and conceptualized the manuscript. G.N. carried out field work (which included collection and identification of plants and collection of environmental data), provided supervision to assure the quality of the database and conducted curation of the database. All authors critically revised the manuscript versions.

Acknowledgements

Financial support was provided by 950629 FITOSOLUM-UCM Research Team.



References

Braun-Blanquet J (1979) *Fitosociología: bases para el estudio de las comunidades vegetales*. Ediciones Blume, Madrid, ES, 820 pp.

Bruelheide H, Dengler J, Jiménez-Alfaro B, Purschke O, Hennekens SM, Chytrý M, Pillar VD, Jansen F, Kattge J, ... Zverev A (2019) sPlot – A new tool for global vegetation analyses. *Journal of Vegetation Science* 30: 161–186. <https://doi.org/10.1111/jvs.12710>

Cabrera AL (1971) *Fitogeografía de la República Argentina*. Boletín de la Sociedad Argentina de Botánica 14(1–2): 1–42.

Cabrera AL (1994) *Regiones fitogeográficas argentinas*. Enciclopedia argentina de agricultura y jardinería. Tomo II, fascículo 1, Editorial ACME S.A.C.I., Buenos Aires, AR, 85 pp.

Cooke RU, Warren A (2020) *Geomorphology in deserts*. University of California Press, US, 440 pp. <https://doi.org/10.1525/9780520329584>

David SGT [Ed.] (1997) *Arid zone geomorphology: process, form and change in drylands*. John Wiley & Sons, UK. <https://doi.org/10.1002/9780470710777>

Dengler J, Jansen F, Glöckler F, Peet RK, De Cáceres M, Chytrý M, Ewald J, Oldeland J, Lopez-Gonzalez G, ... Spencer N (2011) The Global Index of Vegetation-Plot Databases (GIVD): a new resource for vegetation science. *Journal of Vegetation Science* 22: 582–597. <https://doi.org/10.1111/j.1654-1103.2011.01265.x>

Jørgensen PM, Nee MN, Beck SG [Eds] (2015) *Catálogo de las plantas vasculares de Bolivia*. Monographs in Systematic Botany from the Missouri Botanical Garden 127(1–2): 1–1744. Missouri Botanical Garden Press, St. Louis, US.

Molina JA, Navarro G, De la Barra N, Lumbreiras A (2007) Andean aquatic vegetation in Central Bolivia. *Phytocoenologia* 37: 753–768. <https://doi.org/10.1127/0340-269X/2007/0037-0753>

Molina JA, Lumbreiras A, Benavent-González A, Rozzi R, Sancho LG (2016) Plant communities as bioclimate indicators on Isla Navarino, one of the southernmost forested areas of the world. *Gayana Botanica* 73: 391–401. <https://doi.org/10.4067/S0717-66432016000200391>

Moraes M, Sarmiento J (2018) Biodiversity in Bolivia. In: Pulaiah T (Ed.) *Global biodiversity*. Vol. 4, 1–58. <https://doi.org/10.1201/9780429433634-1>

Navarro G (2011) *Clasificación de la Vegetación de Bolivia*. Centro de Ecología Difusión Simón I. Patiño, Santa Cruz de la Sierra, BO, 483–566.

Navarro G, Ferreira W (2009) Biogeografía y mapa biogeográfico de Bolivia. In: *Libro Rojo de Parientes Silvestres de Bolivia VMABCC*. Biodiversity International Plural Editores. La Paz, BO.

Navarro G, Maldonado M (2002) *Geografía ecológica de Bolivia: Vegetación y ambientes acuáticos*. Centro de Ecología Simón I. Patiño, Departamento de Difusión, Cochabamba, BO, 620 pp.

Navarro G, Molina JA (2019) A floristic-ecological classification of the shrublands of the dry Bolivian Altiplano. *Phytocoenologia* 49: 199–208. <https://doi.org/10.1127/phyto/2019/0240>

Navarro G, Molina JA, De la Barra N (2005) Classification of the high-Andean Polylepis forests in Bolivia. *Plant Ecology* 176: 113–130. <https://doi.org/10.1007/s11258-004-0025-1>

Navarro G, Molina JA, Vega S (2011) Soil factors determining the change in forests between dry and wet Chacos. *Flora* 206: 136–143. <https://doi.org/10.1016/j.flora.2010.09.002>

Navarro G, Molina JA, Pérez de Molas L (2006) Classification of the forests of the northern Paraguayan Chaco. *Phytocoenologia* 36: 473–508. <https://doi.org/10.1127/0340-269X/2006/0036-0473>

Navarro G, Molina JA, Agostinelli E, Lumbreiras A, Ferreira W (2010) Towards an ecological classification of flooded savannas in Beni (Bolivia). *Acta Botanica Gallica* 157: 265–273. <https://doi.org/10.1080/12538078.2010.10516204>

Rivas-Martínez S, Navarro G, Penas G, Costa M (2011) Biogeographic Map of South America. A preliminary survey. *International Journal of Geobotanical Research* 1: 21–40. <https://doi.org/10.5616/ijgr110002>

Sabatini FM, Jiménez-Alfaro B, Jandt U, Chytrý M, Field R, Kessler M, Lenoir J, Schrödt F, Wiser S, ... Bruelheide H (2022) Global patterns of vascular plant alpha diversity. *Nature Communications* 13: 4683. <https://doi.org/10.1038/s41467-022-32063-z>

Taber A, Navarro G, Arribas MA (1997) A new park in the Bolivian Gran Chaco—an advance in tropical dry forest conservation and community-based management. *Oryx* 31: 189–198. <https://doi.org/10.1046/j.1365-3008.1997.d01-11.x>

WFO (2021) World Flora Online. [URL:] <http://www.worldfloraonline.org> [accessed 10 Jun 2021]

E-mail and ORCID

Jaime Oliveira (jaimeoli@ucm.es)

José Antonio Molina (Corresponding author, jmabril@ucm.es), ORCID: <https://orcid.org/0000-0003-4348-6015>

Gonzalo Navarro (gonzalonavarrosanchez@gmail.com), ORCID: <https://orcid.org/0000-0001-9890-5112>